Monitoring of nesting sites of olive ridleys and identification of future potential mass nesting sites along the Gahirmatha rookery, Odisha, east coast of India

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Introduction

Sea turtles are known to occupy a series of different habitats in their lifetime which are broadly categorized into the terrestrial habitat of the nesting females and the pelagic and oceanic habitat of the immediate post-hatchling phase. However, the terrestrial habitat of the nesting females plays a very important role in the life cycle of the sea turtles as this is where the next generation is hatched. Female sea turtles need to come onto land to lay eggs for which they must have access to suitable beaches (Hendrickson 1982; Plotkin 2010; Behera *et al.* 2013). Males are restricted to oceanic habitat and after completion of mating they generally leave the breeding ground before the female.

Degradation, transformation and destruction of natural conditions at nesting beaches due to coastal developments continue to threaten the long-term survival of many olive ridley rookeries (Plotkin 2007; Behera & Tripathy 2014). Odisha state along the east coast of India supports a considerable global olive ridley sea turtle population which migrates for breeding with synchronized nesting taking place at some selected locations i.e. Gahirmatha, Devi and Rushikulya. The olive ridley sea turtles (*Lepidochelys olivacea*) are known to make enormous congregations along the Odisha coast between November and April and *arribada* takes place along suitable nesting beaches including Gahirmatha, which is known to be the largest rookery for this species in the world (Bustard 1976; Dash & Kar 1990). The Gahirmatha rookery is located at the mouth of the Maipura and Dhamra rivers, the distributary channels of the Brahmani and Baitarani river systems, belonging to the Mahanadi composite delta in Kendrapada district, north Odisha (Fig. 1).

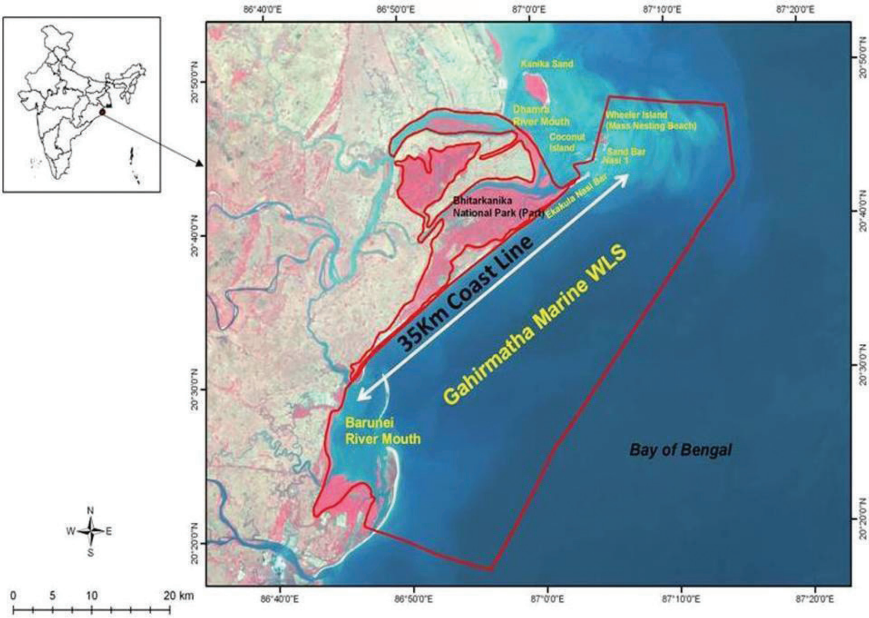

Fig. 1. Map of Gahirmatha Marine Wildlife Sanctuary (WLS) extending 35km along the coastline of Odisha.

Olive ridleys are victims of several threats along the Odisha coast. Apart from bycatch related mortality, on the beach erosion is considered to be the major factor affecting the sea turtles' behaviour directly through the loss of nesting habitat and indirectly through changes in the thermal profiles of the beach (Tripathy & Rajasekhar 2009). However, Gahirmatha rookery has received a high degree of erosion or inundation in the last couple of years that has affected the olive ridley populations (Prusty *et al.* 2007). In this connection this study is focussed on finding a suitable nesting beach for olive ridleys near Gahirmatha rookery.

Materials and methods

The nesting and beach profile study was conducted over 50km to the north and south of Gahirmatha rookery. The total 100km stretch was divided into small segments to cover conveniently the whole nesting stretch for the study of where olive ridley nests were occurring (Fig. 2).

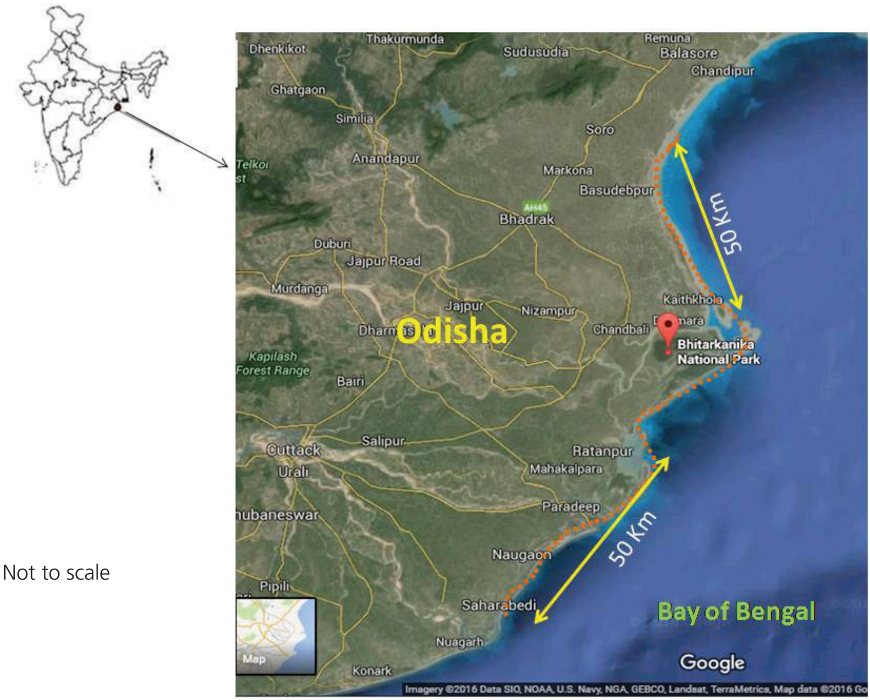

Fig. 2. Beach profiling carried out along 50km either side of Gahirmatha rookery.

The fieldwork was carried out from October 2015 to April 2016 and the entire 100km beach was monitored for enumeration of olive ridley nesting and profiling of the beach. Sporadic nesting data were also recorded during the course of study. For systematic coverage of the sporadic nesting count, the survey was carried out by patrolling each sector in pairs on foot every fourth day. In this way all 20 survey sectors were covered (ten survey sectors on each side of the rookery). Sea turtle crawls on the beach were classified into nesting and non-nesting types. A nesting crawl was characterized by the presence of a nest pit. In contrast, the non-nesting crawls lacked a nest pit and the sea turtle had returned to the sea without nesting (Pandav & Choudhury 2000). Nests were located by following nesting crawls. The status of nest samples was recorded to determine whether in good condition (undisturbed) or predated. Any nest located within two metres of the high tide line, if inundated by sea water, was counted as inundated and these were relocated to the mid part of the beach or placed near the vegetation line. Nests despoiled by predators like wild pig (*Sus scrofa*), hyena (*Hyaena hyaena*), jackal (*Canis aureus*), water monitor lizard (*Varanus salvator*), feral dogs (*Canis familiaris*) and ghost crabs (*Ocypode* spp) were determined by the tracks of the predators. Those nests were counted as predated. At each predated nest, the species of predator was determined from footprints and faeces (Macdonald & Barrett 1993). Observations were by direct sighting as well as evidence of footprints near the degraded nests.

The beach profiling was carried out on a fortnightly basis following standard procedures as suggested by Cooper *et al*. (2000). At every 5km point a permanent landmark was fixed. These points were marked with a handheld GPS (Garmin 72, Garmin Inc.) for subsequent monitoring. Beach width was measured perpendicular from the high tide line (HTL) to the permanent land mark with the help of laser range finder (Nikon 1000 Range Finder).

The formula followed for calculating the available nesting beach at Rushikulya was deduced by Tripathy & Rajasekhar (2009) and Behera *et al*. (2013). Width of the beach $l = a \pm b$, where b is the width of beach from the permanent landmark (a). Finally, the area available for nesting (N) was calculated as average beach width (l) x total length of the beach.

Results

Enumeration of nesting beach profile

The beach profile of the olive ridley nesting beach was enumerated 50km either side of Gahirmatha rookery from Batighara to Saharabedi (Nuliasahi) south and from Kainthakhola to Inchudi north (100km). The 35km Gahirmatha rookery was not accessed as it falls in a protected area so was unavailable for study; earlier data were incorporated. Every 5km interval beach position was recorded during the low tide hour. The highest beach width was recorded during February and the lowest width was in April along the whole nesting stretch. The average beach width between Batighara and Saharabedi (Nuliasahi) was 17.2m (highest in February 42m, range = 10-42m, n = 9), between Dobandi and Chinchiri was 63.08m (highest in February 89.5m, range = 29-135.8m, n = 3), between Chinchiri and Ekakula was 54.9m (highest in February 63.2m, range = 30-107.8m, n = 8) and between Kainthakhola and Inchudi was 12.9m (highest in January 40m, range = 7.8-40m, n = 26). (From Dobandi to Ekakula data were retrieved from 2012; WII-DGH sea turtle project.) There was a significant difference in beach width between different stretches of the 100km of study sites (Kruskal-Wallis test, $p < 0.0001$; Fig. 3). The mean nesting beach width of the entire 100km stretch was found to be 31.9m with ranges from 8-135.8m. It was observed that in November beach width gradually increased, peaked in February and decreased again when erosion started.

Status of sporadic nesting

Sporadic nesting data were determined simultaneously with enumeration of the beach profile of the area, i.e. from Batighara to Saharabedi (Nuliasahi) south and from Kainthakhola to Inchudi north (100km). In November 2015 there were no records of sporadic nesting along the study area. In December 2015 there were records of sporadic nesting in the southern area of Gahirmatha rookery, sector Batighara to Saharabedi (Nuliasahi) and it gradually increased in the month of March while the lowest observation was made in April 2015. However, there were no records of such nesting in the northern part of Gahirmatha rookery (Kainthakhola to Inchudi), though in two or three places there was evidence of a false nesting crawl. As mentioned earlier, the sector in between Dobandi and Ekakula falls under the protected area, so that part was not accessed to estimate sporadic nesting.

Sporadic or solitary nesting was observed in high numbers in the mainland part of the beach. Due to the high availability of nesting space in this part of the beach, most of the sea turtles nest either in a sporadic or solitary way. The study comprised seven months of fieldwork and 210 daily beach surveys of solitary nesting of olive ridleys in Gahirmatha. Altogether, there were 223 nests counted and 1,081 non-nesting crawls recorded.

The frequency of laid nests during the breeding season (December-April) showed a peak of nests in March. Mean number of nests estimated in the 100km study site for the seven months was 29/month (S.D. ± 5.3), with the peak in March (mean = 52.3, S.D. ± 6.9) and least in April (mean = 2.3, S.D. ± 3). The lowest number of nests recorded per kilometre was from Batighara to Saralikud and the highest number of nests observed was in the Saharabedi to Padmapur mainland beach.

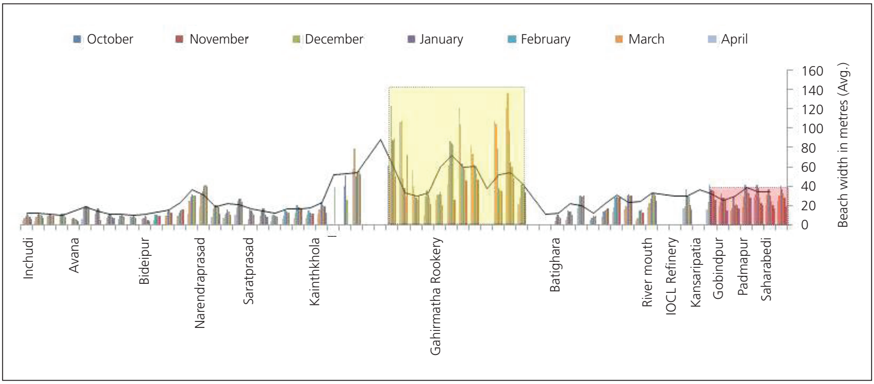

Fig. 3. Bar graph showing availability of the nesting beach 50km either side of Gahirmatha rookery. The rookery (highlighted orange) and the sporadic nesting beach between Saharabedi and Kansaripatia (highlighted pink) show high availability.

Discussion

The geo-environment near the Gahirmatha rookery is extremely complex and sensitive. It consists of estuarine and marine environments separated by a sand spit, which is the most favoured ground for olive ridley nesting. It also covers coastal forests comprising mangrove and mangrove-associated plants, islands, rivers etc. As observed from earlier studies, the geo-environment is undergoing change, which is both temporal and spatial in nature (Prusty *et al*. 2007). The mass nesting beaches including the sand spits have undergone conspicuous temporal changes due to natural disasters like cyclones and interaction of oceanic forces coupled with riverine discharge (Prusty *et al*. 2007). The construction of Dhamra port by DPCL near Gahirmatha mass nesting site and the dredging of ship channels is a major intervention in the shorefront which has brought significant changes in the geomorphology of the nesting beach.

The Gahirmatha rookery is believed to be the largest arribada ground for Olive ridley sea turtles in the world (Bustard 1976). Estimates of annual sea turtle nesting have ranged between 100,000 and 800,000 in different years (Patnaik *et al*. 2001). However, the subsequent trend is that mass nesting has either been taking place in alternate years or apparently absent in some consecutive years (Pandav & Choudhury 2000; Annual Report WII 2009). The failure of mass nesting at Gahirmatha during 1997 and 1998 is a cause for concern due to drastic changes of nesting beach profile (Pandav & Choudhury 2000; Shanker *et al*. 2004). The arribada at Gahirmatha was a continuous event from its discovery in 1974 until 1987.

The mass nesting had been taking place along the 10km mainland beach from Maipura river mouth (i.e. Ekakulanasi to Habalikhati) that was detached from the mainland during a cyclonic storm in 1989, after which the arribada was restricted to a three-km-long island beach. Again, in a 1999 cyclone, the four-km beach was fragmented into two islets *viz*. Nasi-I and Nasi-II. Until 2007, the arribada was occurring at the Nasi-I and Nasi-II with non-occurrence of arribada during 1997, 1998, 2002 (Shanker *et al*. 2004) and 2008, which also happens to be the highest incidence of failure in the documented history at this rookery since its discovery by the scientific community. The fieldwork carried out between 2009 and 2012 revealed the nesting decline at Gahirmatha is likely to be due to the decline in availability of nesting areas on the beach (Behera *et al*. 2015). An earlier study found that there is insufficient beach available for sea turtle nesting except on a 900m island (arribada beach) connecting with Defence Island along 35km of Gahirmatha rookery (Behera *et al*. 2015). Though there was available beach in the northern part of Gahirmatha rookery (Kainthkhola to Inchudi ~5km), nesting was not found except two or three non-nesting crawls. The reason may be that sand is mixed with clay or a more muddy area is present along this stretch. The olive ridley prefers to nest in medium, coarse or fine sand (Rubio, 2009) and with regard to the bathymetry profile sea turtles prefer to congregate in water between 7-20m in depth prior to approaching a nesting beach. Recent studies in India suggested that sea turtles tend to remain in a depth range of 5-30m on the east coast. This reflects the fact that the east coast of Odisha has suitable environmental conditions for olive ridley mass nesting (Mishra *et al*. 2011). In between Kainthkhola and Inchudi there is no such depth of offshore water, which may lead to the absence of nesting in this particular sector of beach, which is a mixture of clay and sand and often in wet condition. However, sea turtles prefer to nest in the southern part of Gahirmatha rookery, as evidenced by the highest sporadic nesting being observed in between Barunei and Satabhaya (Behera *et al*. 2013). As Gahirmatha rookery is a preferred site for olive ridley nesting, the population could move spatially in the event of beach degradation to other suitable beaches for their nesting.

Solitary nesting emergence of olive ridleys is known to occur almost every month along the Gahirmatha coast (Dash & Kar 1990). However, solitary nesting is found in greater numbers during January to May, indicating that this is the main nesting season for this species (Pandav & Choudhury 2000).

The olive ridleys in this study exhibited a preference to dig their nests in locations with no vegetation cover, which has previously been observed in green sea turtles (*Chelonia mydas*) at Tortuguero, Costa Rica, thus becoming prone to predation (Bjorndal *et al.* 1999). Mrosovsky (1983) found in his study that Kemp's ridley sea turtles nest closer to the sea and many nests were inundated by sea water. Our studies also indicate nests deposited within two metres of the high tide line were destroyed by sea water. In some cases the clutches were laid within one metre of the spring high-water line. Several clutches laid below the high-water mark were covered by subsequent high tides in northern Australia (Whiting *et al.* 2007). Rajasekhar and Subba Rao (1988) reported that most nests are dug up by humans (55%) and animals (45%) in Andhra Pradesh, India, and Tripathy *et al*. (2003) reported that almost all solitary nests were destroyed there, mostly by animals. Solitary nest losses by predation were also common during the present study. Predation is also a major cause of losses of nests of sea turtles in many beaches of the world (Stancyk 1995). When walking along the beach searching for olive ridley nests, most of the nests were found to be destroyed by predators like wild pig, feral dog, jackal, hyena and water monitor lizards. The present study indicates there is no suitable nesting beach available for olive ridleys except between Barunei and Satabhaya and the site 60km south of the present arribada beach, i.e. the Saharabedi and Kansaripatia area. The arribada has also occured this year on the 900-metre island beach of Gahirmatha rookery but less intensified nesting has occured (Anonymous, 2016). This arribada beach is dynamic due to erosion and sea turtles may prefer other sites for nest site selection in future. However, the recent developmental activity poses a threat to their nesting beach along the Odisha coast (Behera & Tripathy 2014).

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